Role of Speed Breeding in Crop Improvement

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The global population has been increasing drastically, resulting in an increased demand for food grains. Virtually all sectors of agriculture and related industries have transitioned to modern practices in order to achieve food security. Among the various objectives, accelerating the development of new crop varieties has emerged as the foremost priority for plant breeders. In conventional crop improvement programs, the release of a new variety typically takes a lengthy timeline of approximately 8-10 years.

Starting from the 1940s, plant breeding has harnessed the ability to alter the pace of plant life cycle turnover through methods like single-seed descent and shuttle breeding. NASA's work during the early 1980s served as a source of motivation for plant scientists worldwide. It was in 2003 when scientists at the University of Queensland introduced the term "speed breeding" to describe a collection of methods aimed at expediting the breeding of wheat. In more recent times, scientists have employed controlled-environment (CE) growth conditions to accelerate plant lifecycle. Among the several methods utilized to expedite the growth cycle, Rapid Generation Advancement (which involves inducing stress conditions and cultivating immature embryos in vitro) stands out as a widely adopted approach across many plant families. From the beginning of the 21st century onward, Speed Breeding techniques have been implemented in the Poaceae, Fabaceae, and Brassicaceae families, resulting in an annual generation turnover improvement of up to threefold when compared to traditional plant breeding methods.

Speed breeding results in 3 to 9 generations annually, compared to the 1 to 2 generations achieved through traditional selection methods. Speed breeding can generate crop varieties in a shorter timeframe.

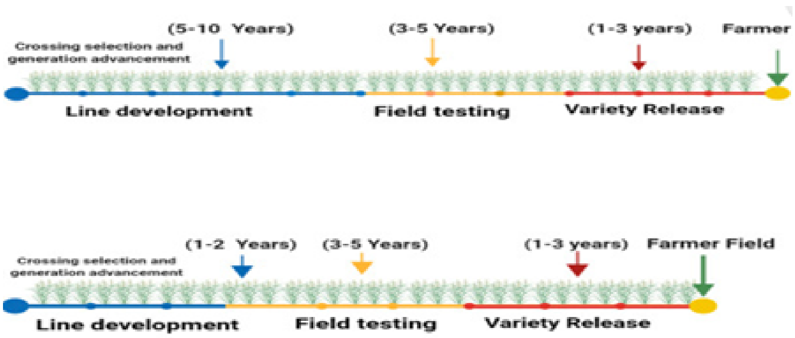


Fig:1 Duration of time to release a new variety by conventional and speed breeding methods

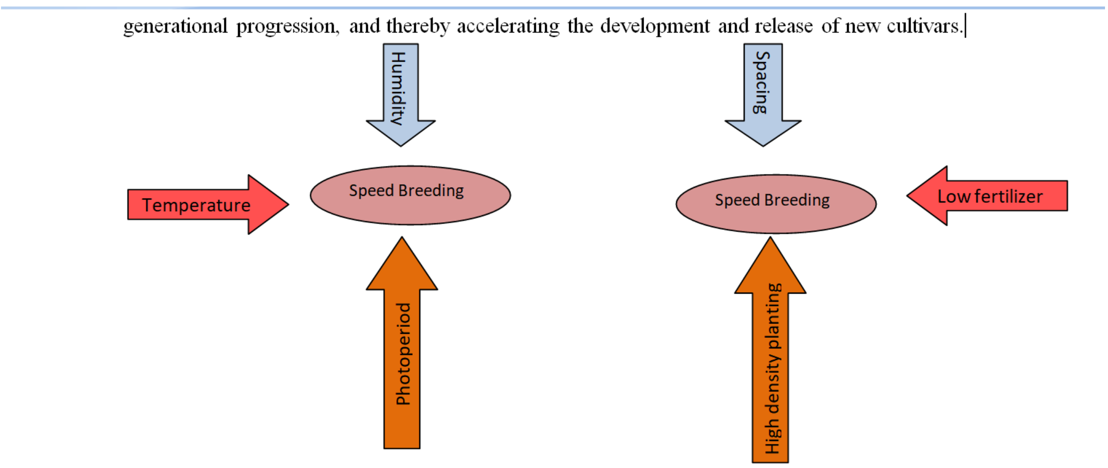
Speed Breeding: The term "speed breeding" refers to a rapid generational advancement technique employed to minimize the duration from seed to seed, consequently shortening the standard life cycle of a crop plant. Speed breeding encompasses a set of techniques designed to swiftly advance to the next generation of breeding stock by manipulating the environmental conditions in which crop genotypes are cultivated. Single Seed Decent (SSD) and Speed Breeding methods are typically used interchangeably. In SSD method, typically, plants are grown in a greenhouse or screen house facility and several generations or cycles are completed between F2 and F6 generations within a quicker time compared to normal field conditions. This is the reason why this method has also been referred to as Rapid Generation Advancement (RGA) method because, as the name implies, the method can expedite the completion of several generations within a reduced timeframe.

Over the past few years, Speed Breeding has seen increased adoption in molecular genetics research for the creation of mapping populations known as recombinant inbred lines (RILs) used in quantitative trait loci (QTL) mapping. These populations are well-suited for QTL mapping due to their genetic homogeneity, and their seeds can be multiplied in large quantities, allowing for the phenotyping of numerous traits over an extended period.

Breeding procedure:

Begna T (2022) stated that Optimal photosynthesis rates can be boosted by carefully regulating factors such as light intensity, temperature (maintaining a 22°C day/17°C night cycle), and daylight duration (22 hours of light), in combination with the practice of yearly seed harvesting to reduce the generation period.

Speed breeding can be followed in both glass house (light, photoperiods, temperature and humidity) and field conditions (high density planting, spacing and lower fertilizer application). Speed breeding enables the rapid generation of homozygous and stable genotypes, expediting generational progression, and thereby accelerating the development and release of new cultivars.



Speed Breeding in glass house condition **Speed Breeding in field condition**

Speed Breeding boosts genetic gain

The equation for genetic gain (ΔG), commonly referred to as the 'breeders' equation,' is expressed as follows: Where, i is the selection intensity, h2 is the trait heritability, σP is the square root of the phenotypic variance and L is the length of the breeding cycle or generation interval.

A straightforward analysis of this formula reveals that a smaller denominator (meaning a shorter breeding cycle) results in greater genetic gain, provided the variables in the numerator remain constant.

As implied by the breeder's equation, the acceleration of plant breeding can be achieved by enhancing factors that impact genetic gain per unit of time, with a primary focus on reducing the breeding cycle time (t).

Advantages:

1. Record keeping is not necessary for RGA.
2. Technically simple, requirement of less field and labour.
3. The cost of breeding lines generated through rapid generation advancement is lower compared to other methods of line generation.
4. Takes less time for development of lines
5. Probability of genetic gain enhancement is higher because of larger population with target trait
6. These populations are excellent for QTL mapping due to their genetic homozygosity.
7. Transgressive segregation can be fixed

8. Maintenance of population is easy

Disadvantages

1. Retention of poor lines during generation advancement,
2. The identity of F2 plants is not retained and within-family selection cannot be practised.

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